COMETARY DUST: THE DIVERSITY OF PRIMITIVE MATTER

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Introduction: The connections between comet dust and primitive chondrites from asteroids has strengthened considerably over the past decade. Understanding the importance of the connections between Stardust samples and chondrites requires geochemistry lingo as well as a perspective of other cometary dust samples besides Stardust. We present the principal findings of an extensive review prepared for by us for the June 2016 "Cometary Science After Rosetta" meeting at The Royal Society, London [1].

Stardust olivine and the Fe—Mn relation: Stardust samples reveal the presence of Fe-rich olivine crystals that are akin to type II chondrules and chondrule fragments. The assessment of minor element concentrations, Mn, Cr, Ca, in olivine is key to connecting individual Stardust olivine grains with olivine grains of similar size (5–30 µm) in the matrices of chondrites and thereby drawing a link between formation conditions for these particles. In this context, the Fe–Mn relation is a well-honed tool for studying the formation conditions of type II chondrules. The Fe–Mn relations displayed by Stardust olivine has strong similarities to CO, CM, CR, CH, and L/LL3.00–3.05 chondrites [2], and encompass the full range of Fe–Mn relations of all primitive chondrites including equilibrated ordinary chondrites (UOCs) and carbonaceous chondrites (CCs) [3]. This implies that type II chondrule-like olivine crystals in comet 81P/Wild 2 are a sampling of chondrule reservoirs more diverse than any single chondrite parent body (asteroid). Dating of the Stardust chondrule Iris puts its formation at ≥3 Myr [4], so comet 81P/Wild 2 formed towards the later times in disk evolution. Stardust samples from comet 81P/Wild 2 show that radial transport was efficient enough for type II chondrule fragments from many different chondrite reservoirs to be transported out to the regime where the comet nucleus was assembled.

Studies of olivine grains in select anhydrous giant chondritic porous interplanetary dust particles (giant CP IDPs) show a similar wide diversity in the Fe–Mn relation as do Stardust samples. A hypothesis is that all comets have this wide diversity of materials and that the body-to-body diversity between comets is minimal [3].

Comparing Stardust to other comet samples: A vital question is whether all comets formed this late and in a disk regime where radial transport allowed incorporation of type II chondrule fragments. To address this question, we consider the Rosetta COSIMA data for dust in the coma of 67P/Churyumov-Gerasimenko (67P) as well as review laboratory investigations of cometary anhydrous interplanetary dust particles (IDPs), cometary chondritic porous interplanetary dust particles (CP IDPs), Ultracarbonaceous Antarctic Micrometeorites (UCAMMs), and remote sensing IR spectroscopy of comet dust. Many anhydrous IDPs have a range of Fe-contents from Mg-rich to Fe-rich (Fa50) [zolensky and Barrett]. On the other hand, GEMS-rich CP IDPs have Mg-rich pyroxene and Mg-rich olivine [5]. GEMS are the amorphous-type silicate species abundant in many cometary IDPs but seemingly absent from Stardust samples. UCAMMs have large concentrations of carbon and GEMS, a shorter range of Fe-contents skewed towards Mg-rich in the pryroxene and olivine crystals, and a higher concentration of S in sulfides than other IDPs [6]. The Fe-contents of most olivines in UCAMMs could be nebular condensates formed under high dust/gas ratios (of ~104) and dissociated water [Fedkin]. In contrast, many of the olivines in Stardust are akin to igneous melts (chondrule fragments). Rosetta's COSIMA-measurements of 67P's coma dust suggest a greater abundance of FeS compared to CI materials [7]. Thus, there are distinctions between Stardust samples and other cometary samples. The characterization of the Wild 2 grains has overtaken the discussion of to that of the IDPs and Rosetta, and so now it is necessary for the latter to catch up.

Acknowledgments: We thank the conveners of the "Cometary Science After Rosetta" meeting.

References:

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